Zoosyst. Evol. 101 (4) 2025, 1763–1774 | DOI 10.3897/zse.101.160089

Description of a new species from eastern Guangxi within the *Oreonectes polystigmus* complex (Cypriniformes, Nemacheilidae) by integrating morphological and genetic evidence

Mei Liao[1*], Jing Yu[2*], Tao Luo[3,4*], Chang-Ting Lan[2], Jia-Jun Zhou[5], Ning Xiao[6], Jiang Zhou[1]

1 *School of Karst Science, Guizhou Normal University, Guiyang 550025, Guizhou, China*
2 *School of Life Sciences, Guizhou Normal University, Guiyang 550001, Guizhou, China*
3 *School of Life Sciences, Yunnan University, Kunming 650504, Yunnan, China*
4 *Southwest United Graduate School, Kunming 650092, Yunnan, China*
5 *Zhejiang Forest Resource Monitoring Center, Hangzhou 310020, Zhejiang, China*
6 *Guiyang Healthcare Vocational University, Guiyang 550081, Guizhou, China*

https://zoobank.org/7A551ED9-E0EC-451F-AD44-BC68F1EDAC0A

Corresponding authors: Ning Xiao (armiger@163.com); Jiang Zhou (zhoujiang@ioz.ac.cn)

Academic editor: Nicolas Hubert ♦ **Received** 24 May 2025 ♦ **Accepted** 9 August 2025 ♦ **Published** 9 September 2025

Abstract

We describe *Oreonectes guidongensis* **sp. nov.**, a new species collected from Hezhou City, Guangxi Zhuang Autonomous Region, China. Morphologically, it is distinguished from all congeners by the following combination of characters: six branched pelvic-fin rays; seven branched dorsal-fin rays; tip of pelvic fin not reaching the anus; a well-developed posterior chamber of the air bladder; 14–16 branched caudal-fin rays; 10 inner gill rakers on the first gill arch; and a distance between the posterior base of the pectoral fin and the anterior base of the pelvic fin of 18.8–27.9% of standard length. Phylogenetic analysis based on the mitochondrial cytochrome b gene supports the distinctiveness of this species, revealing genetic distances of 5.4–8.5% from its congeners. The discovery of *Oreonectes guidongensis* sp. nov. underscores the need to re-evaluate *O. polystigmus* as a potential species complex to better understand the genus's biodiversity.

Key Words

Cryptic species, morphology, taxonomy, phylogeny

Introduction

The genus *Oreonectes* was established by Günther (1868) based on specimens from Hong Kong, China, with *O. platycephalus* Günther, 1868 designated as the type species. Following its initial description, the genus remained monotypic for nearly a century until the description of *O. anophthalmus* Zheng, 1981, and *O. furcocaudalis* Zhu & Cao, 1987, during the 1980s (Zheng 1981; Zhu and Cao 1987). Subsequent taxonomic revisions of the genus *Oreonectes* have relied on both morphological and phylogenetic analyses. Du et al. (2008) classified the genus into two distinct groups based on caudal-fin morphology: the *O. platycephalus* group (characterized by a rounded or truncated caudal fin) and the *O. furcocaudalis* group (exhibiting a forked caudal fin). However, Kottelat (2012) argued that species with forked caudal fins should be excluded from *Oreonectes* based on the original generic diagnosis specifying both caudal-fin morphology and a dorsal-fin origin distinctly anterior to the pelvic-fin origin—a taxonomic contention subsequently resolved

* These authors contributed equally to this paper.

Copyright *Liao, M. et al.* This is an open access article distributed under the terms of the Creative Commons Attribution License (CC BY 4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

when Tang (2012) proposed establishing the new genus *Troglonectes* for species with a *furcocaudalis*-like caudal fin, a classification that was later formally established by Zhang et al. (2016). Recent phylogenetic work by Luo et al. (2023), incorporating extensive molecular data (mitogenomes and seven nuclear genes), has further elucidated the relationships among species within *Oreonectes* and *Troglonectes*. Additionally, their study led to the reclassification of *O. anophthalmus* and *O. acridorsalis* into a newly established genus, *Karstsinnectes* Zhou, Luo, Wang, Zhou & Xiao, 2023, based on congruent morphological and molecular evidence (Luo et al. 2023).

Currently, the genus *Oreonectes* encompasses nine recognized species distributed in mountain streams in the Guangxi Zhuang Autonomous Region, Guangdong, and Hong Kong in China and northern Vietnam (Fig. 1) (Zhu 1989; Kottelat 2012; Lan et al. 2013; Yu et al. 2023; Ito 2024; Luo et al. 2024a). These species are *O. andongensis* Luo, Yang, Du & Luo, 2024, *O. damingshanensis* Yu, Luo, Lan, Xiao & Zhou, 2023, *O. guananensis* Yang, Wei, Lan & Yang, 2011, *O. guilinensis* Huang, Yang, Wu & Zhao, 2020, *O. luochengensis* Yang, Wu, Wei & Yang, 2011, *O. platycephalus*, *O. polystigmus* Du, Chen & Yang, 2008, *O. yuedongensis* Luo, Lan, Xiao & Zhou, 2024, and *O. zhangi* Zhong, Yang & Chen, 2024 (Zhu 1989; Du et al. 2008; Yang et al. 2011a, b; Huang et al. 2020; Yu et al. 2023; Luo et al. 2024a; Zhong et al. 2024; Fricke et al. 2025).

From 2019 to 2024, we collected a large number of *Oreonectes* specimens from the field in Hezhou City, eastern Guangxi, China. These specimens are morphologically similar to *O. polystigmus*. However, through morphological comparisons and genetic analyses with *O. polystigmus* from the type locality, significant differences were identified. Based on these differences, we identified the specimens collected from eastern Guangxi as a new species of the genus *Oreonectes*, named *Oreonectes guidongensis* sp. nov.

Materials and methods

Taxon sampling and morphological analyses

A total of 57 samples of the genus *Oreonectes* were obtained from Guangxi, China (Suppl. material 1). All specimens used for morphological studies were fixed in a 10% formalin buffer and then transferred to 75% ethanol and stored at the Animal Ecology Laboratory of Guizhou Normal University, Guiyang City, Guizhou Province, China.

Morphometric data were collected from 57 well-preserved specimens of the genus *Oreonectes* (Suppl. material 1). A total of 34 measurements were taken on the left side of each specimen to the nearest 0.1 mm using digital calipers, following the protocol of Tang et al. (2012). In addition, morphological data were collected for *O. damingshanensis* and *O. polystigmus* for comparative analysis.

Given the morphological similarity among the new species, *O. polystigmus*, and *O. damingshanensis*, we conducted statistical analyses of their morphometric data. To minimize allometric effects, measurements were size-corrected by normalizing each character to standard length, head length, or caudal peduncle length, following Lan et al. (2024). Principal component analysis (PCA) was applied using eigenvalues greater than 1 and the maximum variance method, supplemented by bivariate scatter plots, to assess morphometric differentiation among the species (Xu et al. 2023). Canonical discriminant analysis (CDA) was used to classify individuals into species groups based on a priori identifications (George and Paul 2010). One-way analysis of variance (ANOVA) was performed to test for significant differences in morphometric characters. All statistical analyses were conducted using SPSS 21.0 (SPSS Inc., Chicago, IL, USA), with significance set at $p < 0.05$.

DNA extraction, sequencing, phylogenetic reconstruction, and genetic distance

Genomic DNA was extracted from muscle tissue using a DNA extraction kit from Tiangen Biotech (Beijing) Co., Ltd. We amplified and sequenced mitochondrial Cyt b from each DNA sample using primers F14724 (5'-GACTTGAAAAACCACCGTTG-3') and R15915 (5'-CTCCGATCTCCGGATTACAAGAC-3') following Xiao et al. (2001). PCR amplifications were performed in a 25-µl reaction volume with the following cycling conditions: an initial denaturing step at 95 °C for 5 min; 36 cycles of denaturing at 95 °C for 40 s, annealing at 50 °C for 40 s, and extension at 72 °C for 1 min; and a final extension at 72 °C for 10 min. Sequencing was performed on an ABI Prism 3730 automated DNA sequencer by Chengdu TSING KE Biological Technology Co., Ltd. (Chengdu, China) (Table 1).

A total of 33 mitochondrial Cyt *b* sequences were included in the phylogenetic analysis (Table 1). Sequences were aligned in MEGA v7.0 (Kumar et al. 2016) using the MUSCLE algorithm with default settings (Edgar 2004). Phylogenetic trees were reconstructed using both maximum likelihood (ML) and Bayesian inference (BI) methods. ML analysis was conducted in IQ-TREE v2.0.4 (Nguyen et al. 2015) under the best-fit model with 2,000 ultrafast bootstrap replicates (Hoang et al. 2018), continuing until a correlation coefficient ≥ 0.99 was reached. BI analysis was performed in MrBayes v3.2.1 (Ronquist et al. 2012) using four Markov chain Monte Carlo (MCMC) chains (three heated, one cold) run for 20 million generations, with sampling every 1,000 generations. Convergence was assessed by ensuring the average standard deviation of split frequencies fell below 0.01. The best-fit models for both ML and BI analyses were selected using the Bayesian information criterion in PartitionFinder v2.1.1 (Lanfear et al. 2017), which identified the first, second, and third codon positions of Cyt *b* as separate partitions with K80+I+G, HKY+I, and TRN+G as the optimal models, respectively. Genetic distances based on Cyt *b* were calculated using the uncorrected p-distance model with 1,000 bootstrap replicates in MEGA v7.0.

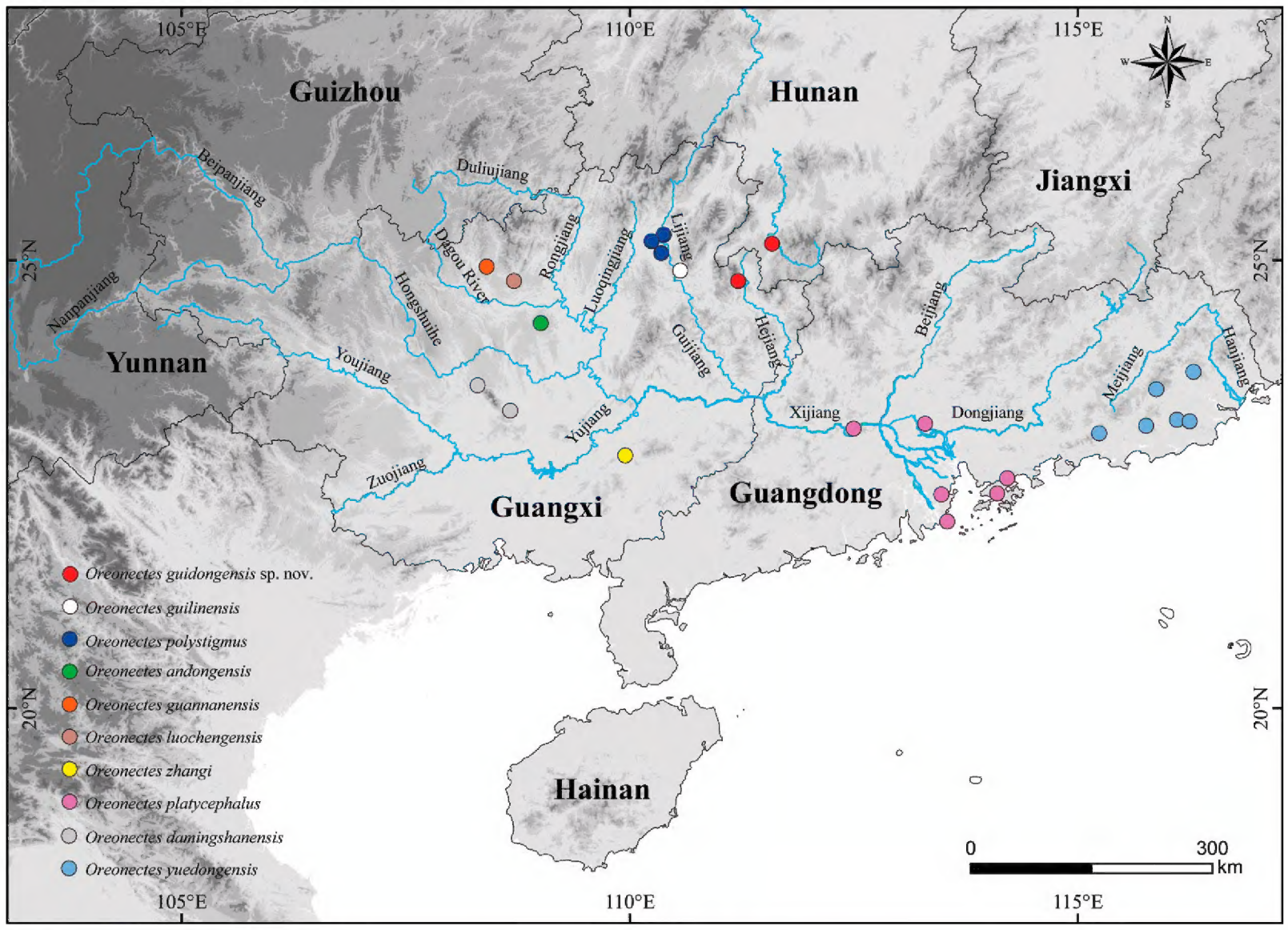

Figure 1. Geographic distribution of recognized *Oreonectes* species, including *O. guidongensis* sp. nov., in southwestern China. Base maps were obtained from the Standard Map Service website (http://bzdt.ch.mnr.gov.cn/index.html).

Table 1. Localities, voucher information, and GenBank numbers for all samples used.

ID	Species	Localities (* type localities)	Voucher	Cyt *b*
1	*O. yuedongensis*	Liangtian Township, Jiexi County, Guangdong, China	GZNU 20230405002	OQ754111
2	*O. yuedongensis*	Hekou Town, Luhe County, Guangdong, China	GZNU 20230405005	OQ754114
3	*O. yuedongensis*	Xiajiashan Town, Puning City, Guangdong, China*	GZNU 20230405004	OQ754113
4	*O. yuedongensis*	Baipenzhu Town, Huidong County, Guangdong, China	GZNU 20230405003	OQ754112
5	*O. yuedongensis*	Yuhu Town, Jieyang City, Guangdong, China	GZNU 20230405006	OQ754115
6	*O. platycephalus*	Shenzhen City, Guangdong, China	GZNU2020112501	ON116528
7	*O. platycephalus*	Baiyun Mountain, Guangzhou City, Guangdong, China	GZNU 20230405007	OR396956
8	*O. platycephalus*	Hengqin Island, Zhuhai City, Guangdong, China	GZNU 20230405010	OR396959
9	*O. platycephalus*	Hong Kong, China*	GZNU 20230405013	OR396962
10	*O. guilinensis*	Xingping Town, Yangshuo County, Guangxi, China*	N/A	MN239094
11	*O. damingshanensis*	Guling Town, Mashan County, Guangxi, China*	GZNU20230216010	OQ754116
12	*O. damingshanensis*	Guling Town, Mashan County, Guangxi, China*	GZNU20230216011	OQ754117
13	*O. damingshanensis*	Guling Town, Mashan County, Guangxi, China*	GZNU20230216012	OQ754118
14	*O. zhangi*	Mt. Hanshan, Xinye County, Yulin City, Guangxi, China*	NNNU2023100202	PP601247
15	*O. polystigmus*	Wanfu Lu Forest Park, Guilin City, Guangxi, China	GZNU2024GL02	PV660724
16	*O. polystigmus*	Wanfu Lu Forest Park, Guilin City, Guangxi, China	GZNU2024GL03	PV660725
17	*O. polystigmus*	Wanfu Lu Forest Park, Guilin City, Guangxi, China	GZNU2024GL04	PV660726
18	*O. polystigmus*	Wanfu Lu Forest Park, Guilin City, Guangxi, China	GZNU2024GL01	PV660723
19	*O. polystigmus*	Wanfu Lu Forest Park, Guilin City, Guangxi, China	GZNU2024GL05	PV660727
20	*O. polystigmus*	Dabu Town, Guilin, Guilin City, Guangxi, China*	GZNU2025O14	PV660730
21	*O. guidongensis* sp. nov.	Laoxi Village, Fuchuan County, Hezhou City, Guangxi, China*	GZNU2024LQ01	PV660728
22	*O. guidongensis* sp. nov.	Jianghua County, Yongzhou City, Hunan, China	GZNU20210609005	ON116517
23	*O. guidongensis* sp. nov.	Laoxi Village, Fuchuan County, Hezhou City, Guangxi, China	GZNU2024LQ02	PV660729
24	*O. guidongensis* sp. nov.	Fuchuan County, Hezhou City, Guangxi, China	GZNU2020011501	ON116514
25	*O. andongensis*	Andong Town, Xincheng County, Laibin City, Guangxi, China*	N/A	OR712240
26	*O. andongensis*	Andong Town, Xincheng County, Laibin City, Guangxi, China*	N/A	OR712241
27	*O. guananensis*	Changmei Town, Huanjiang County, Guangxi, China*	GZNU2020073102	ON116507
28	*O. luochengensis*	Tianhe Town, Luocheng County, Guangxi, China*	GZNU2020011502	ON116495
29	*Guinemachilus bailianensis*	Bailian Cave, Liuzhou City, Guangxi, China*	GZNU2020041603	ON116504
30	*Guinemachilus longibarbatus*	Gaoling Town, Duan County, Guangxi, China*	GZNU2020073104	ON116508
31	*Micronemacheilus cruciatus*	N/A	N/A	AP012142
32	*Micronemacheilus pulcherrimus*	Duan County, Hechi City, Guangxi, China	GZNU20210609004	ON116493
33	*Lefua nikkonis*	N/A	CBM: ZF 11290	AP011300

Results

Morphometric and cluster analysis

The new species differed significantly from *O. polystigmus* and *O. damingshanensis* in 16 and 19 morphological characters, respectively, primarily in body size, head dimensions, fins, and tail features ($p < 0.05$; Suppl. material 2). PCA of 34 morphometric variables identified ten components (eigenvalues > 1.0) that collectively explained 78.43% of the total variance (Suppl. material 3). The first three principal components accounted for 20.16% (PC1), 13.23% (PC2), and 10.00% (PC3) of the variance, respectively. The PC1–PC2 ordination plot revealed distinct clustering patterns, showing clear separation along the PC1 axis between the new species and *O. damingshanensis*, while exhibiting partial overlap with *O. polystigmus* (Fig. 2A). The morphometric separation was primarily driven by seven key variables: body width, head length, predorsal length, prepelvic length, preanal length, distance between posterior nostrils, and caudal peduncle depth (Suppl. material 3). CDA under three initial grouping scenarios achieved 100% correct classification (N = 57), with canonical axes 1 (CAN1) and 2 (CAN2) explaining 78.8% and 21.2% of the total variation, respectively. The CAN1–CAN2 ordination plot demonstrated complete separation between the new species, *O. damingshanensis*, and *O. polystigmus* (Fig. 2B).

Sequence information, phylogeny, and genetic divergence

The mitochondrial Cyt *b* sequence matrix used for molecular analysis comprised 1,140 base pairs, including 759 conserved sites, 381 variable sites, 290 parsimony-informative sites, and 91 singleton sites.

The phylogenetic topologies inferred from both BI and ML analyses were congruent (Fig. 3). In the resulting tree, *O. luochengensis* and *O. guananensis* formed the basal lineages within the genus *Oreonectes*, followed by *O. andongensis*. The four samples collected from Hezhou City, Guangxi, China, clustered together with strong support as the sister lineage to *O. polystigmus* (Fig. 3). Based on Cyt *b* sequences, the genetic distances between the new species and its congeners ranged from 5.4% to 8.5%, exceeding those observed between several recognized species (Table 3). For instance, the genetic distance between *O. damingshanensis* and *O. zhangi* is 4.2%, and between *O. platycephalus* and *O. yuedongensis* is 4.7% (Table 3). The combined morphological and molecular evidence supports the recognition of the Hezhou population as a distinct, previously undescribed species.

Taxonomic account

***Oreonectes guidongensis* Luo, Yu, Liao & Zhou, sp. nov.**

https://zoobank.org/68F7A098-3548-437C-B774-DDDDC81A142B

Tables 2, Fig. 4A–D, Suppl. material 1, 2

Chresonymy. *Oreonectes polystigmus*: Fuli Town and Xinhua Town, Fuchuan County, Guangxi, China (Lan et al. 2013); Jianghua County, Yongzhou City, Hunan, China (Yu et al. 2023; Lan et al. 2024; Luo et al. 2025); and Fuchuan County, Hezhou City, Guangxi, China (Yu et al. 2023; Lan et al. 2024; Luo et al. 2024a; Luo et al. 2025).

Holotype. GZNU20241127001, 63.5 mm TL, 51.7 mm standard length (SL), collected by Jing Yu on March 31, 2024, in Lianshan Town, Hezhou City, Guangxi Zhuang Autonomous Region, China (24.75929000°N, 111.3524400°E; ca. 194 m a.s.l.).

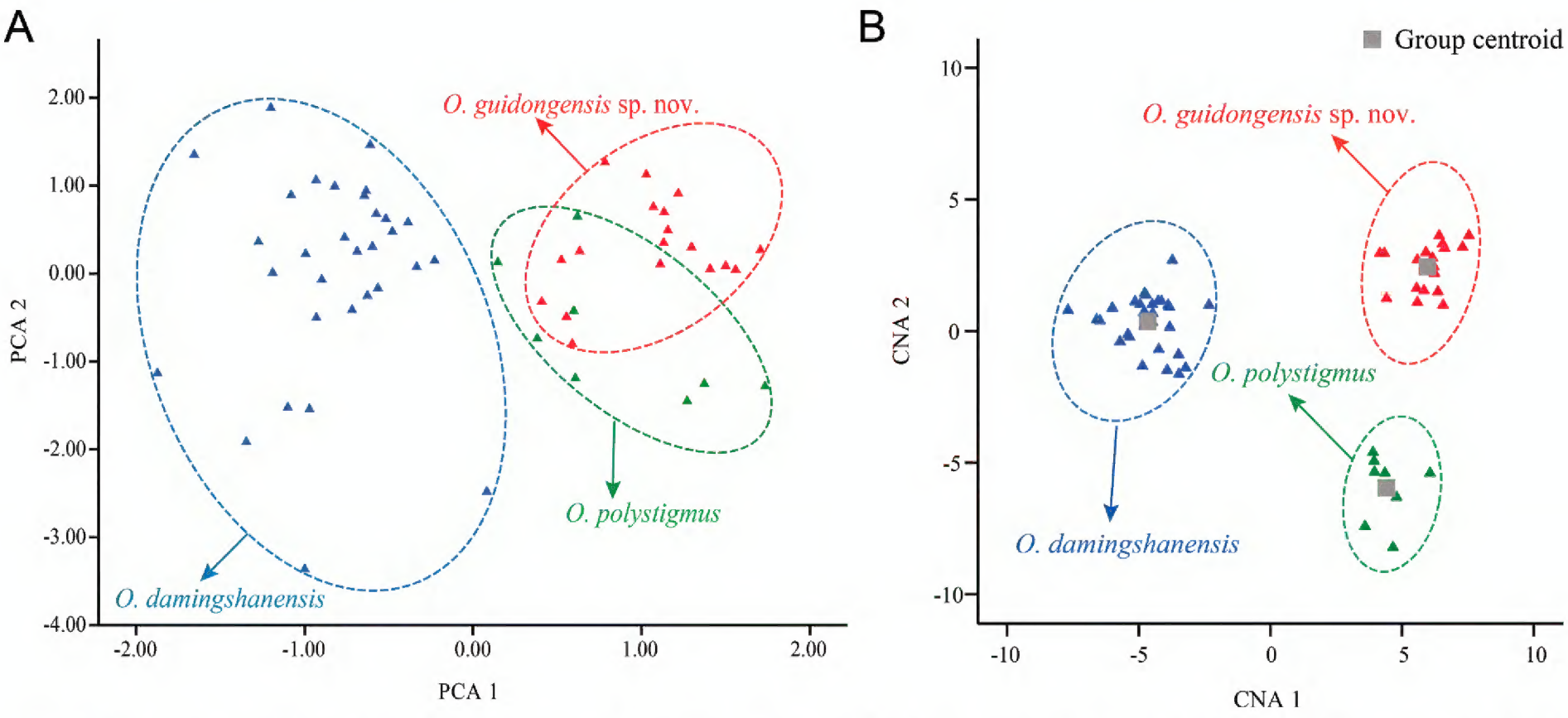

Figure 2. Plots from the principal component analysis (A) and canonical discriminant analysis (B) scores of *O. guidongensis* sp. nov., *O. polystigmus*, and *O. damingshanensis* based on morphological data.

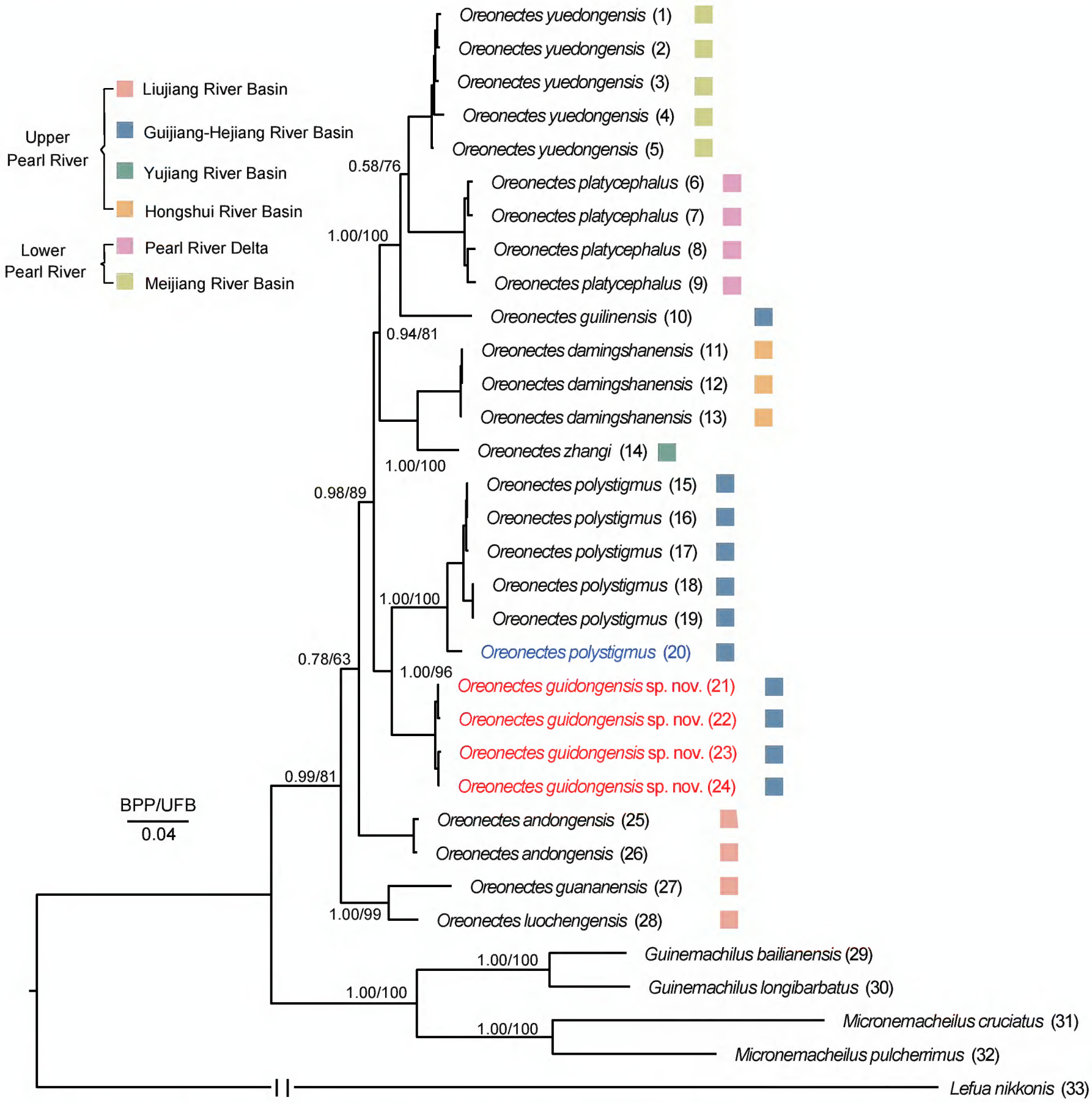

Figure 3. Phylogeny of the genus *Oreonectes*. Bayesian posterior probabilities (BPP) from BI inference and ultrafast bootstrap (UFB) support values from ML analysis are shown at the nodes. The scale bar represents 0.06 nucleotide substitutions per site. Numbers in parentheses correspond to specimen IDs in Table 1. Blue labels indicate samples collected near the near-type locality.

Paratypes. Seventeen specimens from the same locality as the holotype: GZNU20240331007, GZNU20240331012–0331018, GZNU20240531001–0531005, 45.9–59.6 mm SL, collected by Jing Yu and Tao Luo in March and May 2024. GZNU20241127002–1127005, 42.5–59.0 mm SL, collected by Jing Yu and Mei Liao in November 2024.

Etymology. The species name "*guidongensis*" refers to its distribution in Guangxi (广西), also known as Gui (桂), specifically indicating that the species is found in the eastern region of Guangxi, China. The suggested English name for this species is the Guidong Hilly Loach, and its Chinese name is Guì Dōng Lǐng Qiū (桂东岭鳅).

Diagnosis. Comparative data between new species and all nine known species within the genus *Oreonectes* are provided in Table 4. *Oreonectes guidongensis* sp. nov. can be distinguished from *O. platycephalus* and *O. zhangi* by the well-developed posterior chamber of air bladder (vs. reduced), from *O. damingshanensis*, *O. guananensis*, and *O. luochengensis* by six branched plevic-fin rays (vs. 7 or 7–8), from *O. guilinensis* and *O. yuedongensis* by seven branched dorsal-fin rays (vs. 6), from *O. andongensis* 10 inner gill rakers on the first gill arch (vs. 11–12), and from *O. polystigmus* by the tip of pelvic fin not reaching the anus (vs. reaching the anus), distance between the posterior base of the pectoral fin and the anterior base of the pelvic fin is 18.8–27.9% of standard length (18.8–27.9% HL vs. 27.9–34.1%), and five supratemporal pores (vs. 3) (Figs 4, 5).

Table 2. Comparison of morphological measurements between *Oreonectes guidongensis* sp. nov. and its closely related species.

	***O. guidongensis* sp. nov. (*N* = 18)**	***O. polystigmus* (*N* = 8)**	***O. damingshanensis* (*N* = 31)**
	Mean ± SD (range)	**Mean ± SD (range)**	**Mean ± SD (range)**
Total length (mm)	64.3 ± 6.3 (52.7–72.7)	57.5 ± 6.3 (49.0–66.5)	73.9 ± 9.6 (55.7–98.9)
Standard length (mm)	52.7 ± 5.0 (42.5–59.6)	48.3 ± 5.3 (40.3–55.3)	61.0 ± 8.3 (46.2–81.8)
Percentage of SL (%)			
Body depth	15.3 ± 1.3 (13.3–17.6)	15.5 ± 1.2 (13.3–16.9)	15.5 ± 1.3 (12.9–18.6)
Body width	14.4 ± 1.8 (11.3–17.2)	14.4 ± 1.2 (12.5–16.0)	11.3 ± 0.6 (10.3–12.7)
Head length	23.1 ± 1.1 (20.2–24.7)	23.0 ± 1.0 (21.4–24.3)	22.0 ± 0.9 (19.7–23.6)
Predorsal length	60.6 ± 1.2 (58.6–62.5)	58.9 ± 2.0 (56.4–62.2)	60.2 ± 2.0 (56.5–67.2)
Dorsalfin length	18.5 ± 1.1 (16.9–21.7)	18.0 ± 0.7 (16.8–19.3)	18.8 ± 1.8 (13.5–22.6)
Dorsalfin base length	10.2 ± 1.0 (8.3–11.5)	10.4 ± 1.0 (8.3–11.8)	10.2 ± 0.8 (8.3–11.9)
Prepectoral length	22.8 ± 1.1 (21.1–24.9)	22.6 ± 1.6 (21.1–25.6)	21.9 ± 1.2 (19.2–25.2)
Pectoral fin length	18.4 ± 1.1 (16.7–20.5)	15.9 ± 0.9 (14.7–16.9)	16.7 ± 1.1 (14.7–19.5)
Pectoralfin base length	4.2 ± 0.5 (3.4–5.1)	4.0 ± 0.4 (3.4–4.8)	4.0 ± 0.3 (3.6–4.6)
Prepelvic length	53.6 ± 1.2 (51.7–56.5)	54.8 ± 2.2 (51.4–57.7)	51.3 ± 2.0 (48.5–60.0)
Pelvic fin length	15.7 ± 0.7 (14.0–16.9)	13.3 ± 0.9 (12.0–14.6)	15.8 ± 0.8 (13.1–17.2)
Pelvic fin base length	4.1 ± 0.5 (3.2–4.8)	3.5 ± 0.3 (3.2–4.2)	3.8 ± 0.4 (3.1–4.4)
Preanal length	78.8 ± 1.9 (75.4–83.3)	78.6 ± 2.5 (75.8–82.6)	76.0 ± 2.6 (73.2–89.0)
Anal fin length	16.5 ± 0.8 (15.1–18.4)	15.5 ± 1.3 (12.8–16.9)	17.1 ± 1.4 (11.8–19.7)
Anal fin base length	8.3 ± 0.5 (7.5–9.3)	7.4 ± 1.4 (5.5–9.6)	8.6 ± 0.7 (7.1–10.6)
Caudal peduncle length	13.5 ± 1.3 (11.6–16.6)	14.4 ± 1.0 (12.8–15.5)	15.3 ± 1.2 (13.4–17.8)
Caudal peduncle depth	11.1 ± 0.6 (10.1–12.3)	11.2 ± 0.8 (10.0–12.4)	10.9 ± 0.6 (10.1–12.3)
Distance between anal fin and posterior margin of anus	5.8 ± 0.5 (5.1–7.0)	5.3 ± 0.4 (4.5–5.9)	5.9 ± 1.4 (3.1–12.1)
Distance between pectoral and pelvic fins	21.5 ± 2.2 (18.8–27.9)	30.4 ± 2.3 (27.9–34.1)	27.6 ± 1.6 (24.9–31.8)
Distance between pectoral and anal fins	26.5 ± 2.3 (22.3–30.1)	21.4 ± 2.1 (18.8–25.1)	21.5 ± 2.2 (18.9–29.0)
Preanterior nostril length	4.1 ± 1.3 (2.1–6.2)	5.4 ± 1.0 (3.6–6.5)	3.8 ± 0.7 (2.4–4.9)
Percentage of HL (%)			
Head depth	53.4 ± 5.6 (44.3–65.3)	53.1 ± 2.7 (49.7–57.1)	53.8 ± 2.9 (45.5–58.1)
Head width	74.5 ± 4.3 (68.2–83.7)	65.5 ± 4.9 (55.0–72.0)	72.5 ± 4.9 (59.4–79.0)
Snout length	39.0 ± 2.0 (36.0–43.2)	38.6 ± 1.6 (36.2–41.0)	41.3 ± 1.8 (37.9–45.3)
Out rostral barbel length	55.6 ± 6.8 (45.6–68.6)	48.0 ± 5.4 (40.2–56.0)	51.6 ± 4.8 (42.4–62.4)
Inrostral barbel length	36.5 ± 4.7 (28.1–47.3)	34.9 ± 3.0 (29.1–38.5)	33.7 ± 3.3 (25.9–38.3)
Maxillary barbel length	49.7 ± 5.7 (37.5–59.0)	44.6 ± 4.9 (37.4–53.2)	43.8 ± 5.2 (36.0–56.6)
Eye diameter	12.1 ± 2.2 (10.1–16.9)	14.8 ± 1.5 (11.7–16.2)	12.6 ± 1.6 (8.5–15.7)
Interorbital distance	39.4 ± 3.3 (35.0–46.7)	38.8 ± 1.9 (35.4–41.1)	42.6 ± 3.7 (34.8–57.0)
Mouth width	37.2 ± 1.9 (34.3–40.5)	39.9 ± 1.7 (37.8–42.2)	35.2 ± 5.4 (18.0–41.6)
Upper jaw length	28.2 ± 1.8 (26.2–32.1)	27.9 ± 1.2 (26.2–29.7)	24.0 ± 2.8 (15.8–29.2)
Lower jaw length	21.9 ± 2.2 (19.0–27.2)	23.6 ± 1.7 (20.5–26.2)	18.8 ± 2.5 (12.9–22.9)

Table 3. Uncorrected *p*-distances (%) between seven species of the genus *Oreonectes* based on the mitochondrial Cyt *b* gene.

ID	Species	1	2	3	4	5	6	7	8	9
1	*O. guidongensis* sp. nov.									
2	*O. polystigmus*	5.8								
3	*O. andongensis*	6.2	6.8							
4	*O. damingshanensis*	6.0	6.9	6.5						
5	*O. guananensis*	8.5	8.6	8.0	8.8					
6	*O. guilinensis*	7.4	8.2	7.4	7.2	8.8				
7	*O. luochengensis*	7.6	7.6	6.9	7.6	4.9	8.1			
8	*O. platycephalus*	6.7	7.3	7.0	6.8	8.8	6.4	8.1		
9	*O. yuedongensis*	5.4	6.4	5.9	5.9	7.1	5.2	6.5	4.7	
10	*O. zhangi*	6.6	7.1	7.1	4.2	9.1	7.3	7.3	7.2	5.8

Description. Morphometric data are given in Table 2 and Suppl. material 1. Dorsal-fin rays iii-7, pectoral-fin rays i-10, pelvic-fin rays i-6, anal-fin rays iii-5, 14–16 branched caudal-fin rays, and 10 inner gill rakers on the first gill arch.

Body elongated and cylindrical, deepest body depth in front of dorsal-fin origin, deepest body depth of 13.3–17.6% SL, with the insignificant depth decreasing from dorsal-fin origin to caudal-fin base. Head short, slightly depressed and flattened, maximum width greater than deepest depth (head width/head depth = 1.2–1.7). Snout round, oblique, and flat, length 36.0–43.2% of head length (HL). Mouth inferior, curved, upper and lower lips smooth, lower lip with a V-shaped median notch. Three pairs of barbels are long: inrostral barbel length 28.1–47.3% of HL, tips reaching the anterior margin of the eye; outrostral barbel length 45.6–68.6% of HL, tips beyond the posterior margin of the eye. Maxillary barbel length 37.5–59.0% of HL, tips not reaching to the posterior margin of the gill cover. Anterior and posterior nostrils narrowly separated, with an interspace of approximately 1.2 mm. Anterior nostril tube short, with an elongated short barbel-like tip. Eyes normal, diameter of 10.1–16.9% HL. Gill opening small; gill rakers not developed, and 10 inner gill rakers on the first gill arch.

Dorsal fin short, length 16.9–21.7% of SL, pre-dorsal length 58.6–62.5% of SL, distal margin round, origin posterior to pelvic-fin origin. Pectoral fin short, length 16.7–20.5% of SL, pre-pectoral length 21.1–24.9% of SL, tips

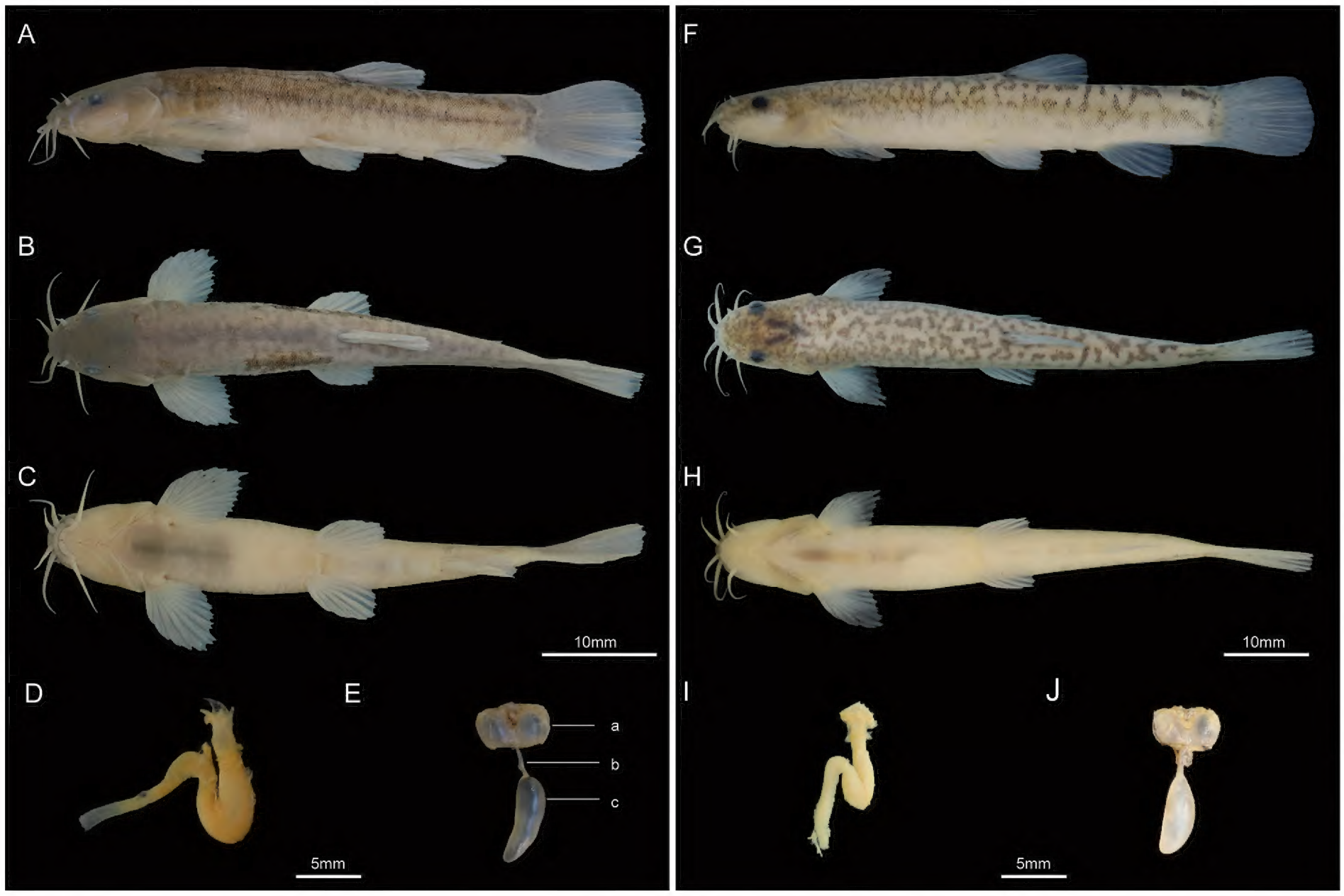

Figure 4. Morphological characteristics of *O. guidongensis* sp. nov. (holotype, GZNU20241127001; **A–E**) and *O. polystigmus* (**F–J**) in preservative (10% formalin). **A, F.** Lateral view; **B, G.** Dorsal view; **C, H.** Ventral view; **D, I.** Stomach; **E, J.** Air bladder. anterior chamber (**a**), tube connecting anterior and posterior chambers of the air bladder (**b**), and posterior chamber (**c**).

reaching about half of the distance between the origin of pectoral and pre-pelvic fins. Pelvic-fin length 14.0–16.9% of SL, pre-pelvic length 51.7–56.5% of SL, tips not reaching the anus. Anal fin long, length 15.1–18.4% of SL, tips not reaching the caudal-fin base. Caudal fin rounded, caudal peduncle length 11.6–16.6% of SL, without adipose crests along either dorsal or ventral sides.

Body completely covered with fine scales, except for head, thorax, and abdomen. Lateral line incomplete, exceeding tip of pectoral fin but not reaching the caudal fin base, with 6–10 pores, last lateral line pore not reaching the tip of pectoral fin. Cephalic lateral-line system, with 7–8 supraorbital, 4 + 11 infraorbital canal pores, 5 supratemporal canal pores, with 6–7 preoperculo-mandibular canal pores (Fig. 5A1–A3). Stomach U-shaped with straight intestines (Fig. 4D). Anterior chamber covered by dumbbell-shaped bony capsule, posterior chamber well-developed, and tube connecting anterior and posterior chambers of the air bladder (Fig. 4E). Lateral wall of the bony capsule of the swim bladder is membranous and closed posteriorly (Fig. 4E).

Sexual dimorphism. In males, a genital papilla is present immediately posterior to the anus, with the gonopore opening at the tip of a fleshy prominence (Fig. 5C1, C2).

Coloration. In life, overall body light yellowish brown with many obvious speckles, dark brown between anterior margin of eyes to outrostral barbel; dorsum with irregular brown spots; dorsal and caudal fins dark brown at base (Fig. 6A). In 10% formalin the body color was dark brown.

Distribution, habitat, and populations. Based on recent surveys, the new species *Oreonectes guidongensis* sp. nov. is widely distributed in streams of Fuchuan County, Hezhou City, Guangxi, China, within the Guijiang–Heijiang River basin of the Pearl River system. It is also found in Jianghua County, Yongzhou City, Hunan Province (Fig. 1). The species occurs in large populations in its known habitats and is relatively easy to collect.

Morphological comparison with the congeners. Comparative data of *Oreonectes guidongensis* sp. nov. with the nine recognized species within the genus *Oreonectes* are given in Table 4.

Oreonectes guidongensis sp. nov. can be distinguished from *O. luochengensis* by body pigmentation absent (vs. present), 10 branched pectoral-fin rays (vs. 11–12), six branched pelvic-fin rays (vs. 7), and ten inner gill rakers on the first gill arch (vs. 13–14).

Oreonectes guidongensis sp. nov. can be distinguished from *O. zhangi*, *O. yuedongensis*, and *O. damingshanensis* by 10 branched pectoral-fin rays (vs. 8–9). *Oreonectes guidongensis* sp. nov. can be further distinguished from *O. zhangi* by 10 inner gill rakers on the first gill arch (vs. 9) and developed posterior chamber of air bladder (vs. reduced); from *O. yuedongensis* by seven branched

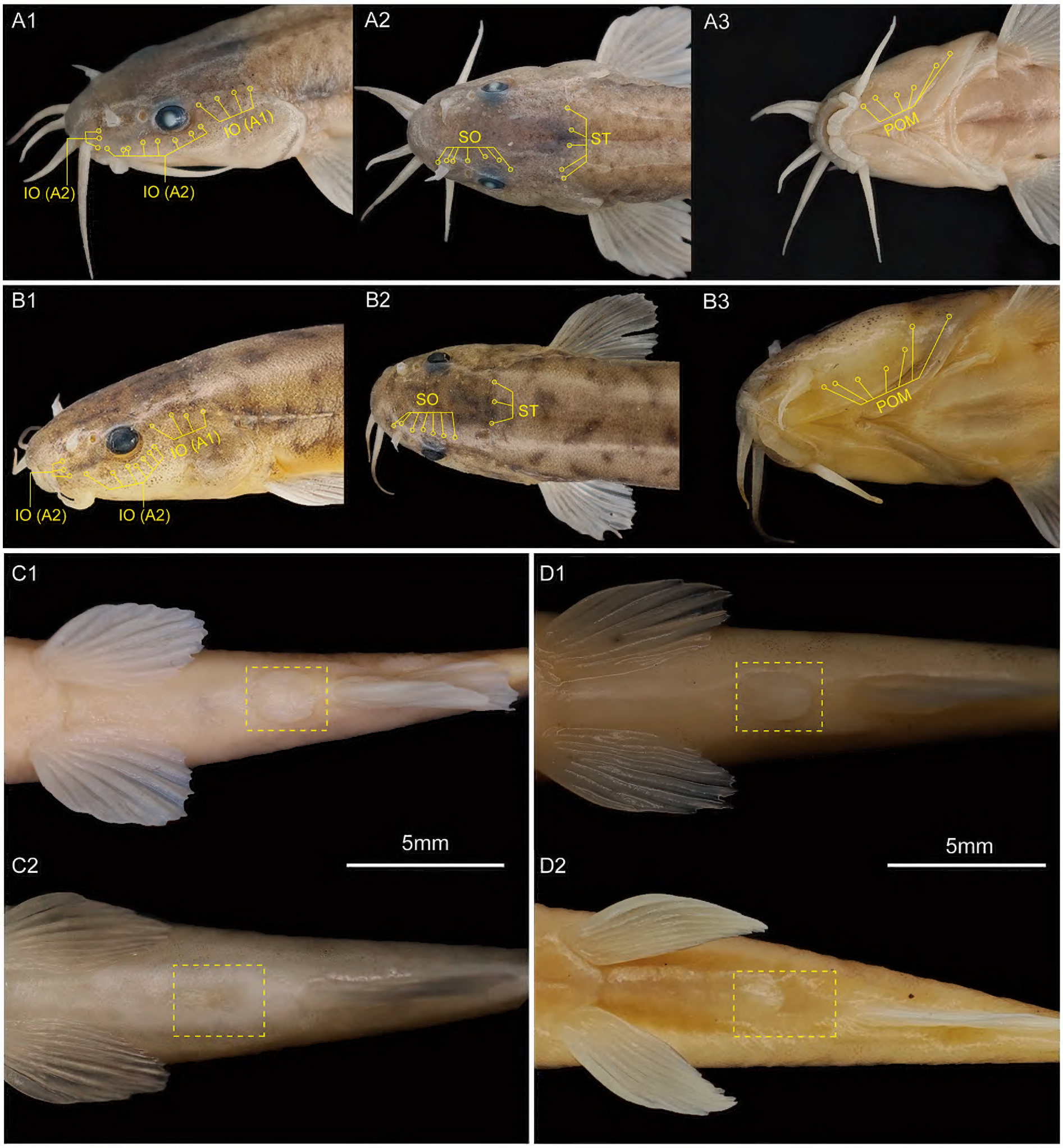

Figure 5. Dephalic lateral-line system and gonadal structure of *Oreonectes guidongensis* sp. nov. (A and C) and *O. polystigmus* (B and D). **A1, B1.** Lateral view; **A2, B2.** Dorsal view; **A3, B3.** Ventral view; **C1, C2.** Male and females of *Oreonectes guidongensis* sp. nov.; **D1, D2.** Male and females of *O. polystigmus*. IO, pores of infraorbital canal (A1 + A2); POM, pores of preoperculo-mandibular canal; SO, pores of supraorbital canal; ST, pores of supratemporal canal.

dorsal-fin rays (vs. 6) and tip of pelvic fin not reaching the anus (vs. reaching the anus); and from *O. damingshanensis* by six branched pelvic-fin rays (vs. 7) and 10 inner gill rakers on first gill arch (vs. 8).

Oreonectes guidongensis sp. nov. can be distinguished from *O. guananensis* by six branched pelvic-fin rays (vs. 7–8), 10 inner gill rakers on the first gill arch (vs. 11), and body with obvious speckles (vs. absent); from *O. guilinensis* by seven branched dorsal-fin rays (vs. 6); from *O. platycephalus* by seven branched dorsal-fin rays (vs. 6), six branched pelvic-fin rays (vs. 7), and developed posterior chamber of air bladder (vs. reduced); and from *O. andongensis* by 10 inner gill rakers on the first gill arch (vs. 11–12).

Oreonectes guidongensis sp. nov. is phylogenetically and morphologically close to *O. polystigmus* but can be distinguished by a combination of the following characters: tip of pelvic fin not reaching anus (vs. reaching anus) (Fig. 5), distance between the posterior base of the pectoral fin and the anterior base of the pelvic fin is 18.8–27.9% of standard length (vs. 27.9–34.1%), cephalic lateral-line

Table 4. Comparison of diagnostic characters between the new species and its congeners. Grey shading highlights characters that clearly differ from those of *O. guidongensis* sp. nov. Modified from Zhong et al. (2024).

Species	Body pigmentation	Dorsal-fin rays	Pectoral-fin rays	Pelvic-fin rays	Anal-finrays	Caudal-finrays	Gill rakers	Posterior chamber of air bladder	Tip of pelvic fin
O. guidongensis sp. nov.	Present	iii, 7	i, 10	i, 6	iii, 5	14–16	10	Developed	Not reaching the anus
O. andongensis	Present	iii, 7	i, 9–10	i, 6	iii, 5	13–14	11–12	Developed	Not reaching the anus
O. damingshanensis	Present	iii, 7	i, 9	i, 7	iii, 5	14–15	8	Developed	Not reaching the anus
O. guananensis	Present	iii, 7	i, 10–11	i, 7–8	iii, 5	13–17	11	Developed	Not reaching the anus
O. guilinensis	Present	ii, 6	i, 9–10	i, 6	iii, 5	13–14	–	Well-developed	Not reaching the anus
O. luochengensis	Absent	iii, 7	i, 11–12	i, 7	ii, 5	14–16	13–14	Developed	Not reaching the anus
*O. platycephalus**	Present	iii, 6	i, 10–11	i, 7	iii, 5–6	13–15	–	Reduced	Not reaching the anus
O. polystigmus	Present	iii, 6–7	i, 10	i, 6	ii, 5	14–15	–	Developed	Reaching the anus
O. yuedongensis	Present	iii, 6	i, 8–9	i, 6	iii, 5	13	9–10	Well-developed	Reaching the anus
O. zhangi	Present	iii, 7	i, 8–9	i, 6	iii, 5	15–16	9	Reduced	Not reaching the anus

* indicates data from 15 syntypes provided by Ito (2024) and this study.

system, and five supratemporal pores (vs. 3). In addition, the new species and *O. polystigmus* showed significant differences in 47% of the 34 morphological characters measured, including total length, predorsal length, pectoral fin length, pelvic fin length, pelvic fin base length, anal fin length, anal fin base length, distance between anal fin and posterior margin of anus, distance between pectoral and pelvic fins, distance between pectoral and anal fins, preanterior nostril length, head width, out rostral barbel length, maxillary barbel length, eye diameter, and mouth width (Suppl. material 2).

Discussion

In this study, we describe a new species, *Oreonectes guidongensis* sp. nov. Morphologically, it closely resembles *O. polystigmus* but can be distinguished by several diagnostic characters (see Diagnosis). The distinctiveness of the new species is further supported by genetic evidence. The discovery of *O. guidongensis* sp. nov. increases the number of recognized species in the genus *Oreonectes* to ten, contributing to a better understanding of its species diversity.

A recent taxonomic study has preliminarily clarified the systematic classification and distributional boundaries of the *Oreonectes platycephalus* complex in Guangdong Province, China (Lan et al. 2024). However, members of the *O. platycephalus* complex have also been widely reported in Guangxi, including Du'an, Mashan, Luocheng, Rong'an, Jinxiu, Xingye, and Zhaoping counties (Zheng 1989; Zhu 1989; Du et al. 2008; Zhang et al. 2016; Gan et al. 2017; Xiao and Lan 2023; Zhong et al. 2024). Due to a lack of genetic data, the phylogenetic placement of *O. platycephalus* populations in these areas remains uncertain. In central Guangdong, *O. platycephalus* is distributed near the Pearl River estuary, within the Pearl River Delta (Fig. 1). In contrast, three species are currently recorded from the Guijiang–Heijiang River basin in Guangxi: *O. guidongensis* sp. nov., *O. guilinensis*, and *O. polystigmus*. Although geographically adjacent (Fig. 1), these species are genetically distinct, with pairwise distances ranging from 5.8% to 7.4% (Table 3). Notably, each species is associated with a different drainage within the Pearl River system, from the upper to lower reaches (Fig. 3). We hypothesize that this distribution pattern reflects historical geographic isolation driven by riverine erosion and the geomorphic evolution of the Pearl River basin—similar to the evolutionary history of the genus *Sinocyclocheilus* (Wen et al. 2022), the genus *Karstsinnectes* (Luo et al. 2024b), and Chinese hypogean fishes (Luo et al. 2025)—though further investigation is required to test this hypothesis.

The phylogeny and classification of the genus *Oreonectes* have advanced rapidly over the past three years. Recent studies have clarified its phylogenetic relationships with related genera (Du et al. 2023; Luo et al. 2023) and described several new species (Yu et al. 2023; Lan et al. 2024; Luo et al. 2024b). However, limited species sampling, restricted survey coverage, and insufficient data have contributed to continued uncertainty in the interspecific phylogeny. Although morphometric data are available for most species, several key taxonomic characters remain underreported, including skeletal structures from micro-CT scans, the morphology of the posterior chamber of the air bladder, and stomach structure. We recommend incorporating these anatomical features into future species descriptions and taxonomic studies to improve the classification and evolutionary understanding of the genus *Oreonectes*.

Figure 6. Ecological photographs of four species of the *O. polystigmus* complex. (**A**) *O. guidongensis* sp. nov. (**B**) *O. polystigmus*. (**C**) *O. zhangi*. (D) *O. damingshanensis*.

Acknowledgments

We thank Yi-Xuan Zhang from Guangxi Normal University for providing the near-type locality specimens of *Oreonectes polystigmus*. We also thank LetPub (www.letpub.com) for its linguistic assistance during manuscript preparation.

This research was supported by the programs "Endangerment processes and mechanisms of endangered flagship animals" (2022YFF1301502), "Diversity and distribution survey of Chiroptera species in China" (2021FY100302), and the Guizhou Normal University Academic Emerging Talent Fund Project (Qianshi Xin Miao [2021] 20).

References

Du LN, Chen XY, Yang JX (2008) A review of the Nemacheilinae genus *Oreonectes* Günther with descriptions of two new species (Teleostei: Balitoridae). Zootaxa 1729: 23–36. https://doi.org/10.11646/zootaxa.1729.1.3

Du LN, Li SJ, Xu F, Luo T, Luo FG, Yu GH, Zhou J (2023) Clarification of Phylogenetic Relationships among Chinese Nemacheilids with Tube-Shaped Anterior Nostrils, with a Description of a New Genus and Two New Species. Journal of Zoological Systematics and Evolutionary Research 2023(1): 3600085. https://doi.org/10.1155/2023/3600085

Edgar RC (2004) MUSCLE: Multiple sequence alignment with high accuracy and high throughput. Nucleic Acids Research 32(5): 1792–1797. https://doi.org/10.1093/nar/gkh340

Fricke R, Eschmeyer WN, Van der Laan R [Eds] (2025) Eschmeyer's Catalog of Fishes: Genera, Species, References. http://researcharchive.calacademy.org/research/ichthyology/catalog/fishcatmain.asp [Electronic version accessed 8, August, 2025]

Gan X, Lan JH, Wu TJ, Yang J (2017) Photographic Guide To freshwater Fishes in South China. Henan Science and Technology Press, Zhengzhou. [In Chinese]

George D, Paul M (2010) SPSS for Windows step by step: A Simple study guide and reference, 18.0 Update (11th edn.). Prentice Hall, New Jersey, USA.

Günther A (1868) Catalogue of the fishes in the British museum. Trustees of the British Museum, London.

Hoang DT, Chernomor O, von Haeseler A, Minh BQ, Vinh LS (2018) UFBoot2: Improving the ultrafast bootstrap approximation. Molecular Biology and Evolution 35(2): 518–522. https://doi.org/10.1093/molbev/msx281

Huang JQ, Yang J, Wu ZQ, Zhao YH (2020) *Oreonectes guilinensis* (Teleostei, Cypriniformes, Nemacheilidae), a new loach species from Guangxi, China. Journal of Fish Biology 96(1): 111–119. https://doi.org/10.1111/jfb.14191

Ito T (2024) *Lefua hoffmanni* Herre 1932, a junior synonym of *Oreonectes platycephalus* Günther 1868 (Cypriniformes: Nemacheilidae). Zootaxa 5448(4): 519–530. https://doi.org/10.11646/zootaxa.5448.4.5

Kottelat M (2012) Conspectus cobitidum: an inventory of the loaches of the world (Teleostei: Cypriniformes: Cobitoidei). The Raffles Bulletin of Zoology 26(6): 1–199. https://doi.org/10.1016/j.sleep.2014.01.018

Kumar S, Stecher G, Tamura K (2016) MEGA7: Molecular evolutionary genetics analysis version 7.0 for bigger datasets. Molecular Biology and Evolution 33(7): 1870–1874. https://doi.org/10.1093/molbev/msw054

Lan JH, Gan X, Wu TJ, Yang J (2013) Cave Fishes of Guangxi, China. Science Press, Beijing. [In Chinese]

Lan CT, Luo T, Zhao XR, Yu J, Xiao N, Zhou J (2024) *Oreonectes yuedongensis* (Cypriniformes, Nemacheilidae), a new freshwater fish species from the Lianhua Mountains in eastern Guangdong, China. Journal of Fish Biology 105(6): 1731–1746. https://doi.org/10.1111/jfb.15909

Lanfear R, Frandsen PB, Wright AM, Senfeld T, Calcott B (2017) PartitionFinder 2: New methods for selecting partitioned models of evolution for molecular and morphological phylogenetic analyses. Molecular Biology and Evolution 34(3): 772–773. https://doi.org/10.1093/molbev/msw260

Luo T, Yang Q, Wu L, Wang YL, Zhou JJ, Deng HQ, Xiao N, Zhou J (2023) Phylogenetic relationships of cavefishes of the Namacheilidae (*Heminoemacheilus*, *Oreonectes*, *Yunnanilus*, *Paranemachilus*, and *Troglonectes*) revealed by phylogenetic analysis of mitochondrial genome and seven nuclear genes. Zoological Research 44(4): 693–697. https://doi.org/10.24272/j.issn.2095-8137.2022.266

Luo XM, Yang RG, Du LN, Luo FG (2024a) A new loach species of the genus *Oreonectes* (Teleostei, Cypriniformes, Nemacheilidae) from Guangxi, China. ZooKeys 1196: 285–301. https://doi.org/10.3897/zookeys.1196.109810.figure1

Luo T, Luo FW, Lan CT, Xiao MY, Zhou JJ, Liao M, Xiao N, Zhou J (2024b) Evolutionary history of Chinese karst loaches (Nemacheilidae, *Karstsinnectes*): New insights from mitochondrial-based genomes and description of a new species from Guangxi, China. Zoosystematics and Evolution 100(4): 1473–1486. https://doi.org/10.3897/zse.100.133964

Luo T, Lan CT, Yu J, Song LX, Fan C, Wang JJ, Zhou JJ, Xiao N, Zhou J (2025) Rapid speciation of Chinese hypogean fishes driven by paleogeoclimatic and morphological adaptations. Current Zoology, zoaf010. https://doi.org/10.1093/cz/zoaf010

Nguyen LT, Schmidt HA, Von HA, Minh BQ (2015) IQ-TREE: A fast and effective stochastic algorithm for estimating maximum-likelihood phylogenies. Molecular Biology and Evolution 32(1): 268–274. https://doi.org/10.1093/molbev/msu300

Ronquist F, Teslenko M, Van DMP, Ayres DL, Darling A, Höhna S, Larget B, Liu L, Suchard MA, Huelsenbeck JP (2012) MrBayes 3.2: Efficient Bayesian phylogenetic inference and model choicem across a large model space. Systematic Biology 61(3): 539–542. https://doi.org/10.1093/sysbio/sys029

Tang L (2012) Study on taxonomy and distribution patterns of the genera *Oreonectes* and *Troglonectes* gen. nov. (Cypriniformes: Balitoridae) (Master's thesis). University of Chinese Academy of Sciences, Beijing. [In Chinese]

Tang L, Zhao YH, Zhang CG (2012) A new blind loach, *Oreonectes elongatus* sp. nov. (Cypriniformes: Balitoridae) from Guangxi, China. Environmental Biology of Fishes 93: 483–449. https://doi.org/10.1007/s10641-011-9943-7

Wen H, Luo T, Wang Y, Wang S, Liu T, Xiao N, Zhou J (2022) Molecular phylogeny and historical biogeography of the cave fish genus *Sinocyclocheilus* (Cypriniformes, Cyprinidae) in southwest China. Integrative Zoology 17(2): 311–325. https://doi.org/10.1111/1749-4877.12624

Xiao S, Lan JH (2023) Guangxi Danshui Yulei Feilei Tujian. Henan Science and Technology Press, Zhengzhou. [In Chinese]

Xiao WH, Zhang YP, Liu HZ (2001) Molecular systematics of Xenocyprinae (Teleostei: Cyprinidae): taxonomy, biogeography, and coevolution of a special group restricted in East Asia. Molecular Phylogenetics and Evolution 18(2): 163–173. https://doi.org/10.1006/mpev.2000.0879

Xu C, Luo T, Zhou JJ, Wu L, Zhao XR, Yang HF, Xiao N, Zhou J (2023) *Sinocyclocheilus longicornus* (Cypriniformes, Cyprinidae), a new species of microphthalmic hypogean fish from Guizhou, Southwest China. ZooKeys 1141: 1–28. https://doi.org/10.3897/zookeys.1141.91501

Yang J, Wu TJ, Wei RF, Yang JX (2011a) A new loach, *Oreonectes luochengensis* sp. nov. (Cypriniformes: Balitoridae) from Guangxi, China. Zoological Research 32(2): 208–211. [In Chinese]

Yang Q, Wei ML, Lan JH, Yang Q (2011b) A new species of the genus *Oreonectes* (Balitoridae) from Guangxi, China. Guangxi Normal University: Natural Science Edition 29(1): 72–75. [In Chinese]

Yu J, Luo T, Lan CT, Zhou JJ, Deng HQ, Xiao N, Zhou J (2023) *Oreonectes damingshanensis* (Cypriniformes, Nemacheilidae), a new species of stream fish from Guangxi, Southwest China. ZooKeys 1180: 81–104. https://doi.org/10.3897/zookeys.1180.104645

Zhang CG, Zhao YH, Xing YC, Zhou W, Tang WQ (2016) Species diversity and distribution of inland fishes in China. Science Press, Beijing. [In Chinese]

Zheng BS (1981) Freshwater fishes of Guangxi Province. Guangxi People's Publishers, Nanning. [In Chinese]

Zheng CY (1989) Fishes of the Zhujiang River. Science Press, Beijing. [In Chinese]

Zhong JH, Yang J, Mo HL, Chen WC (2024) Description of a new species of the genus *Oreonectes* (Teleostei, Cypriniformes, Nemacheilidae) from Guangxi, China. Zoosystematics and Evolution 100(4): 1259–1267. https://doi.org/10.3897/zse.100.125866

Zhu SQ (1989) The loaches of the subfamily Nemacheilinae in China (Cypriniformes: Cobitidae). Jiangsu Science and Technology Publishing House, Nanjing. [In Chinese]

Zhu SQ, Cao WX (1987) The noemacheiline fishes from Guangdong and Guangxi with descriptions of a new genus and three new species (Cypriniformes: Cobitidae). Acta Zootaxonomica Sinica 12(3): 323–331. [In Chinese]

Supplementary material 1

Morphological characters and measurement data of the new species *O. guidongensis* sp. nov., *O. damingshanensis*, and *O. polystigmus*

Authors: Mei Liao, Jing Yu, Tao Luo, Chang-Ting Lan, Jia-Jun Zhou, Ning Xiao, Jiang Zhou

Data type: xlsx

Explanation note: *indicates the holotype.

Copyright notice: This dataset is made available under the Open Database License (http://opendatacommons.org/licenses/odbl/1.0/). The Open Database License (ODbL) is a license agreement intended to allow users to freely share, modify, and use this Dataset while maintaining this same freedom for others, provided that the original source and author(s) are credited.

Link: https://doi.org/10.3897/zse.101.160089.suppl1

Supplementary material 2

Morphological comparisons of *Oreonectes guidongensis* sp. nov. (OG), *O. polystigmus* (OP), and *O. damingshanensis* (OD)

Authors: Mei Liao, Jing Yu, Tao Luo, Chang-Ting Lan, Jia-Jun Zhou, Ning Xiao, Jiang Zhou

Data type: xlsx

Copyright notice: This dataset is made available under the Open Database License (http://opendatacommons.org/licenses/odbl/1.0/). The Open Database License (ODbL) is a license agreement intended to allow users to freely share, modify, and use this Dataset while maintaining this same freedom for others, provided that the original source and author(s) are credited.

Link: https://doi.org/10.3897/zse.101.160089.suppl2

Supplementary material 3

Results and percentage of variance explained by principal component analysis

Authors: Mei Liao, Jing Yu, Tao Luo, Chang-Ting Lan, Jia-Jun Zhou, Ning Xiao, Jiang Zhou

Data type: xlsx

Copyright notice: This dataset is made available under the Open Database License (http://opendatacommons.org/licenses/odbl/1.0/). The Open Database License (ODbL) is a license agreement intended to allow users to freely share, modify, and use this Dataset while maintaining this same freedom for others, provided that the original source and author(s) are credited.

Link: https://doi.org/10.3897/zse.101.160089.suppl3